Attorney Docket No.: VX992028

Date: November 4, 1999

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Dear Sir:

Transmitted herewith for filing is the **UTILITY** patent application of:

Inventor(s): Katsutomo Terashima, et al.

Title: EXCIMER LASER DEVICE AND GAS FOR EXCIMER LASER

☒ 14 pages of written description, claims and abstract.
☒ SIX sheet(s) of formal drawings.
☒ Executed Declaration and Power of Attorney
☒ Assignment Papers (cover sheet and documents)
☐ Certified Copy of Priority Documents
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EXCIMER LASER DEVICE AND GAS FOR EXCIMER LASER

Background of the Invention

1. Field of the Invention

The present invention relates to an excimer laser device in which gas for excimer laser is sealed in a chamber, pulse oscillation is carried out in the chamber to excite the gas for the excimer laser so to oscillate the pulsed laser, and gas for excimer laser, and more particularly to an excimer laser device which improves a burst phenomenon and a spiking phenomenon of a laser output by adding xenon gas, and gas for excimer laser.

2. Description of the Related Art

Conventionally, a semiconductor exposure device provided with an excimer laser device as a light source alternately repeats the exposure and the movement of the stage to expose an IC chip on a semiconductor wafer to light, so that the excimer laser device performs a burst operation which repeats a continuous pulse oscillating operation for continuously oscillating a pulse of laser light for a predetermined number of times and a suspension of oscillation for suspending the pulse oscillation for a predetermined duration.

Fig. 6(a) is a diagram showing a relation between energy and a burst number when the burst operation is performed by a conventional excimer laser device. It is seen that the burst operation of the excimer laser device has a characteristic (hereinafter called the burst characteristic) that energy is

high at first and lowers gradually.

Fig. 6(b) is a diagram showing a relation between a pulse and energy at each burst. It is seen that the continuous pulse oscillating operation has a characteristic (hereinafter called the spike characteristic) that energy is relatively high at the beginning and then pulse energy lowers gradually.

Thus, when the existing excimer laser device is used to perform the burst operation, the burst characteristic and the spike characteristic are demonstrated generally.

But, the occurrence of the burst characteristic in the laser output by the excimer laser device had a drawback of causing variations in an amount of light exposure due to variations in energy at each burst.

There was also a drawback that when the spike characteristic was caused in the laser output, accuracy of the amount of light exposure was further lowered, so that it was necessary to make complex discharge voltage control.

Specifically, the discharging voltage was conventionally changed for each pulse by lowering the discharging voltage (charging voltage) of the initial pulse of the continuous pulse oscillation in the burst mode and gradually increasing the following discharging voltage of the pulse, thereby preventing the initial energy increase due to the spiking phenomenon. Therefore, complex control of the discharging voltage was necessary.

Thus, in performing the burst operation of the excimer laser device, it was a very significant issue to efficiently remedy the burst characteristic and the spike characteristic

of the laser output.

"Transmission Properties of Spark Preionization Radiation in Rare-Gas Halide Laser Gas Mixes" disclosed in "IEEE JOURNAL OF ELECTRONICS, VOL. 31, No. 12, December 1995, p2195-p2207" suggests a technology of adding xenon gas to neon gas alone. But, this conventional technology is a technology just to increase the spark preionization but not to remedy the burst characteristic and the spike characteristic of the excimer laser output.

Summary of the Invention

It is an object of the present invention to provide an excimer laser device, which can efficiently improve burst and spike characteristics of an excimer laser output in burst operation, and gas for excimer laser.

In order to achieve the aforesaid object, the aspect of the invention according to claim 1 relates to an excimer laser device in which gas for excimer laser is sealed in a chamber and pulse oscillation is carried out in the chamber to excite the gas for excimer laser so to oscillate pulsed laser, wherein a predetermined amount of xenon gas in a predetermined concentration is supplied to the gas for excimer laser in the chamber to lower burst and spiking phenomena caused in an excimer laser output.

Thus, the aspect according to claim 1 can readily improve the excimer laser output and stabilize the output without involving complex control because the predetermined amount of xenon gas in the predetermined concentration is supplied to

the gas for excimer laser in the chamber to resolve the burst and spiking phenomena caused in the excimer laser output.

The aspect of the invention according to claim 2 relates to an excimer laser device which comprises: a xenon gas cylinder in which the xenon gas to be supplied to the chamber is sealed; sensing means for detecting a concentration of the xenon gas added to the gas for excimer laser in the chamber; and control means for controlling an amount of the xenon gas supplied from the xenon gas cylinder to the chamber based on the concentration of the xenon gas detected by the sensing means.

Thus, the aspect according to claim 2 can readily improve the excimer laser output and stabilize the output by mounting the xenon gas cylinder, the detecting means and the control means to a conventional excimer laser device because the concentration of the xenon gas added to the gas for excimer laser in the chamber is detected, and the supply amount of the xenon gas sealed in the xenon gas cylinder to the chamber is controlled according to the detected concentration of the xenon gas.

The aspect of the invention according to claim 3 relates to gas for excimer laser used for an excimer laser device which oscillates pulsed laser by exciting gas for excimer laser sealed in a chamber, wherein the gas for excimer laser contains at least a predetermined concentration of xenon gas.

Thus, the aspect according to claim 3 is configured to contain at least the predetermined concentration of xenon gas in addition to halogen gas in the gas for excimer laser, so

that the excimer laser output can be readily improved and the output can be stabilized by merely supplying the gas for excimer laser into the chamber.

The aspect of the invention according to claim 4 relates to gas for excimer laser which contains 200 ppm or below of the xenon gas.

Brief Description of the Drawings

Fig. 1 is a block diagram showing a structure of an excimer laser device used in an embodiment of the invention;

Figs. 2(a) and 2(b) are diagrams exemplifying burst and spike characteristics when gas for excimer laser with xenon gas added is used;

Fig. 3 is a diagram showing a correlation between an amount of xenon gas added to gas for excimer laser filled in the chamber shown in Fig. 1 and an energy value of laser output and its variations;

Fig. 4 is a diagram showing a correlation between an amount of xenon added to gas for excimer laser and a burst characteristic;

Fig. 5 is a diagram showing a correlation between an amount of xenon added to gas for excimer laser and a spike characteristic;

Figs. 6(a) and 6(b) are diagrams showing a relation between energy and a burst number, etc. when a burst operation is performed by a conventional excimer laser device.

Description of the Preferred Embodiments

An embodiment of the invention will be described with reference to the accompanying drawings.

Fig. 1 is a block diagram showing the structure of the excimer laser device used in the embodiment of the invention.

The excimer laser device shown in Fig. 1 is a device which has gas for excimer laser, which is composed of buffer gas such as Ne, rare gas such as Ar or Kr, halogen gas such as F2 and xenon (Xe) gas, sealed into chamber 10 and excites the gas for excimer laser by the electrical discharge across discharging electrodes to carry out pulse laser oscillation.

This excimer laser device has a feature of adding xenon gas to the gas for excimer laser instead of preparing the excimer laser gas from only buffer gas and halogen gas different from a conventional way. The xenon gas was added to the gas for excimer laser in order to remedy a burst phenomenon and a spiking phenomenon which are caused in the excimer laser output.

The excimer laser device of Fig. 1 has the chamber 10, narrow-band making unit 11, partial penetration mirror 12, Ar/Ne gas cylinder 13, Ar/F2/Ne gas cylinder 14, Xe gas cylinder 15, Xe gas sensor 16, gas exhaust module 17 and gas controller 18.

The chamber 10 is a sealing medium for sealing the gas for excimer laser prepared by mixing Ne, Ar, F2 and Xe gases, and the narrow-band making unit 11 is a unit for making emitted pulse light to have a narrow band and comprises prism beam expander and grating (not shown). And, the partial penetration mirror 12 is a mirror for making penetration

output of only a part of the oscillated laser light.

The Ar/Ne gas cylinder 13 is a gas cylinder for storing a mixture gas of argon and neon, the Ar/F2/Ne gas cylinder 14 is a gas cylinder for storing a mixture gas of argon, neon and fluorine, and the Xe gas cylinder 15 is a compact gas cylinder for storing xenon gas.

The Xe gas sensor 16 is a gas sensor for detecting a ratio of xenon gas or the like contained in the gas for excimer laser sealed into the chamber 10, and the gas exhaust module 17 is a module externally discharging the excimer laser gas from the chamber 10.

The gas controller 18 is a controller which controls based on the detection output of the Xe gas sensor 16 the supply of Ar/Ne gas from the Ar/Ne gas cylinder 13 to the chamber 10, the supply of Ar/F2/Ne gas from the Ar/F2/Ne gas cylinder 14 to the chamber 10, the supply of xenon gas from the Xe gas cylinder 15 to the chamber 10, and the exhaust of the gas for excimer laser by the gas exhaust module 17.

Thus, this excimer laser device is configured by mounting the compact Xe gas cylinder 15 to a conventional excimer laser device, detects a ratio of xenon gas by the Xe gas sensor 16, and controls the supply of xenon gas from the Xe gas cylinder 15 to the chamber 10 by the gas controller 18.

The burst characteristic and the spike characteristic, when the excimer laser gas with xenon gas added is used, will be described.

Fig. 2 is a diagram showing an example of the burst characteristic and the spike characteristic when the gas for

excimer laser with xenon gas added is used. In this case, 10 ppm of xenon gas was added to the gas for excimer laser.

As shown in Fig. 2(a), where xenon gas is not added (see the characteristic indicated at the lower part of the drawing) and an energy value of the initial burst is assumed to be 1, the burst characteristic is that the energy value becomes small as the number of times of burst increases and converges to about 40% (0.4) of the initial value.

On the other hand, where 10 ppm of xenon gas is added (see the characteristic indicated at the upper part of Fig. 2(a)), the number of times of burst until the energy value converges is small, and energy which lowers as the number of times of burst increases is small. Besides, the energy value of each burst where 10 ppm of xenon gas is added is far larger than no addition of the xenon gas.

As described above, when 10 ppm of xenon gas is added, the burst characteristic is remarkably improved as compared with no addition of the xenon gas.

As shown in Fig. 2(b), where the xenon gas is not added (see the characteristic curve indicated at the lower part of the drawing) and an energy value of the initial burst is assumed to be 1, the spike characteristic is that the energy value becomes small as the number of times of pulsing increases and converges to about 40% (0.4) of the initial value. Therefore, the pulse in the spike portion can not be used practically until the energy converges with the progress of the pulse oscillation.

On the other hand, where 10 ppm of xenon gas is added

(see the characteristic curve indicated at the upper part of Fig. 2(b)), the spike portion is substantially removed, the energy value converges very quick, and deviations (3σ) of the energy value is greatly improved. And, where 10 ppm of xenon gas is added, each pulse energy value is far larger than no addition of the xenon gas.

As described above, the addition of 10 ppm of xenon gas greatly improves the spike characteristic as compared with no addition of the xenon gas.

Now, a correlation between an amount of xenon added to the gas for excimer laser sealed in the chamber 10 shown in Fig. 1 and the energy value of laser output and its variations will be described.

Fig. 3 is a diagram showing a correlation between an amount of xenon added to the gas for excimer laser sealed in the chamber 10 shown in Fig. 1 and the energy value of laser output and its variations (3σ).

As shown in Fig. 3, where xenon gas is not added, the energy value obtained is only about 25% of the maximum output obtained when it is added, but the energy value is quickly increased by gradually increasing the amount of xenon gas added (0 to 10 ppm).

Specifically, when xenon gas is added in an amount of 0 to 2 ppm, the output energy is increased rapidly, when it is added in a range of 2 to 10 ppm, the output energy is substantially flat, and when it is added in an amount of 10 ppm, the energy value becomes maximum. And, when the added amount of xenon gas is further increased, the energy value

lowers gradually.

When the addition of xenon gas is gradually increased (0 to 10 ppm), the variations (3σ) of the energy value are decreased, and when its added amount becomes about 10 ppm, the variations in the energy value become minimum (about 25%). And, when the added amount of xenon gas is continuously increased, the variations (3σ) are increased.

In terms of the energy efficiency and the stability of energy, the addition of about 10 ppm of xenon gas is most efficient. But, even the addition of about 200 ppm of xenon gas can improve the energy value and its variations compared with no addition of xenon gas.

The burst characteristic and the spike characteristic with variable amounts of xenon added to the gas for excimer laser sealed into the chamber 10 of Fig. 1 will be decried with reference to Fig. 4 and Fig. 5.

Fig. 4 is a diagram showing a correlation between the amount of xenon added to the gas for excimer laser and the burst characteristic.

As shown in Fig. 4, when xenon gas is not added (0 ppm), there is caused a burst characteristic that an output light energy value is gradually lowered with the increase of the number of times of burst and converges to a certain value. When xenon gas of 10 ppm, 20 ppm, 50 ppm or 100 ppm is added, the number of times of burst until the output light energy converges is decreased.

When 10 ppm of xenon gas is added, the energy value becomes maximum, then the energy value of each burst lowers

every time the added amount of xenon gas is increased. But, even when 100 ppm of xenon gas is added, the energy value of each burst is larger than no addition of xenon gas.

It is seen from the above that the burst characteristic is basically improved by adding xenon gas, and the addition of about 10 ppm of xenon gas is most efficient.

Fig. 5 is a diagram showing a correlation between the amount of xenon gas added to the gas for excimer laser and the spike characteristic.

As shown in Fig. 5, when xenon gas is not added (0 ppm), there is caused a spike characteristic that the energy value lowers gradually until a pulse exceeds a predetermined level, but when the xenon gas of 10 ppm, 20 ppm, 50 ppm or 100 ppm is added, the spike characteristic is greatly improved.

And, when 10 ppm of xenon gas is added, the energy value becomes maximum, and the pulse energy value lowers every time the added amount of xenon gas is increased. But, even when 100 ppm of xenon gas is added, the pulse energy value is larger than no addition of the xenon gas.

It is seen from the above that the spike characteristic is basically improved by adding xenon gas, and the addition of about 10 ppm of xenon gas is most efficient.

As described above, the present embodiment, which is configured by mounting the compact Xe gas cylinder 15 to a conventional excimer laser device, detects a ratio of xenon gas by the Xe gas sensor 16, and controls the supply of xenon gas from the Xe gas cylinder 15 to the chamber 10 by the gas controller 18, provides the following effects.

(1) Burst and spiking phenomena caused in the excimer laser output can be lowered.

(2) The excimer laser output can be stabilized readily without involving complex control.

(3) The excimer laser output can be stabilized with a conventional excimer laser device used as a basic structure.

In the aforesaid embodiment, the Xe gas cylinder 15 and the like were added to a conventional excimer laser device. But, the present invention is not limited to it and can also have a gas cylinder, in which the gas for excimer laser with xenon gas added is sealed, and supply the gas for excimer laser directly from the gas cylinder to the chamber 10.

What is claimed is:

1. An excimer laser device in which gas for excimer laser is sealed in a chamber and pulse oscillation is carried out in the chamber to excite the gas for excimer laser so to oscillate pulsed laser, wherein a predetermined amount of xenon gas having a predetermined concentration is supplied to the gas for excimer laser in the chamber to lower burst and spiking phenomena caused in an excimer laser output.

2. An excimer laser device according to claim 1, comprising:

a xenon gas cylinder in which the xenon gas to be supplied to the chamber is sealed;

sensing means for detecting a concentration of the xenon gas added to the gas for excimer laser in the chamber; and

control means for controlling an amount of the xenon gas supplied from the xenon gas cylinder to the chamber based on the concentration of the xenon gas detected by the sensing means.

3. Gas for excimer laser used for an excimer laser device which oscillates pulsed laser by exciting gas for excimer laser sealed in a chamber, wherein the gas for excimer laser contains at least a predetermined concentration of xenon gas.

4. Gas for excimer laser according to claim 3, wherein the gas for excimer laser contains 200 ppm or below of the xenon gas.

Abstract of the Disclosure

Burst and spike characteristics in an excimer laser output in a burst operation are efficiently improved. Xenon gas is added from a compact Xe gas cylinder to gases for excimer laser in a chamber supplied from an Ar/Ne gas cylinder and an Ar/F2/Ne gas cylinder, a ratio of the xenon gas is detected by an Xe gas sensor, and the supply of the xenon gas from the Xe gas cylinder to the chamber is controlled by a gas controller.

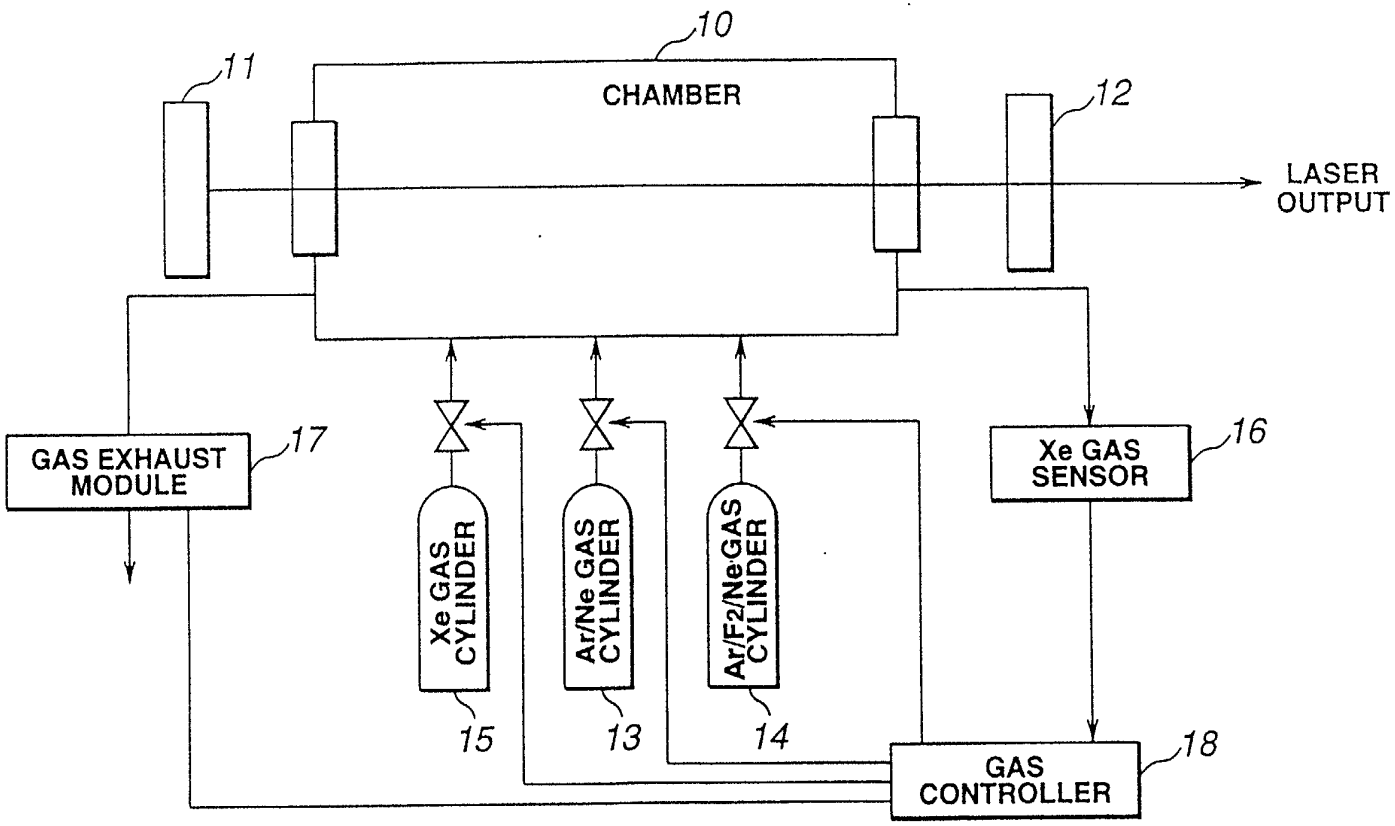

10
11
CHAMBER
12
LASER
OUTPUT
GAS EXHAUST
MODULE
17
Xe GAS
CYLINDER
Ar/Ne GAS
CYLINDER
Ar/F2/NeGAS
CYLINDER
Xe GAS
SENSOR
16
15
13
14
GAS
CONTROLLER
18

FIG.1

FIG.2(a)

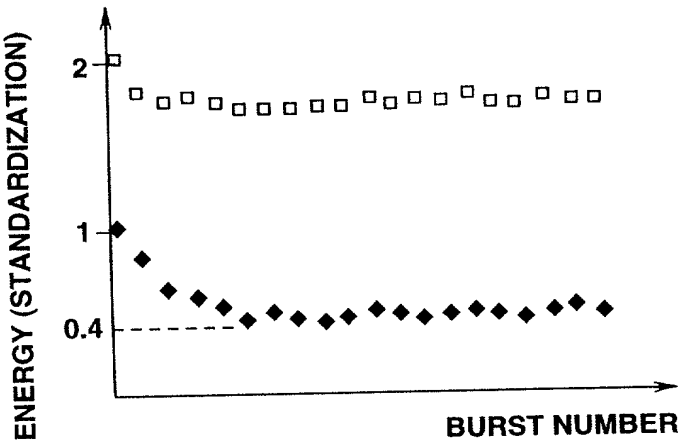
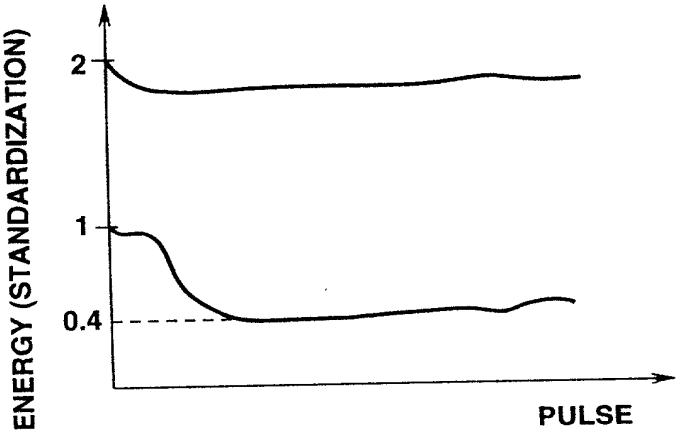

ENERGY (STANDARDIZATION)
2
1
0.4
BURST NUMBER

FIG.2(b)


ENERGY (STANDARDIZATION)
2
1
0.4
PULSE

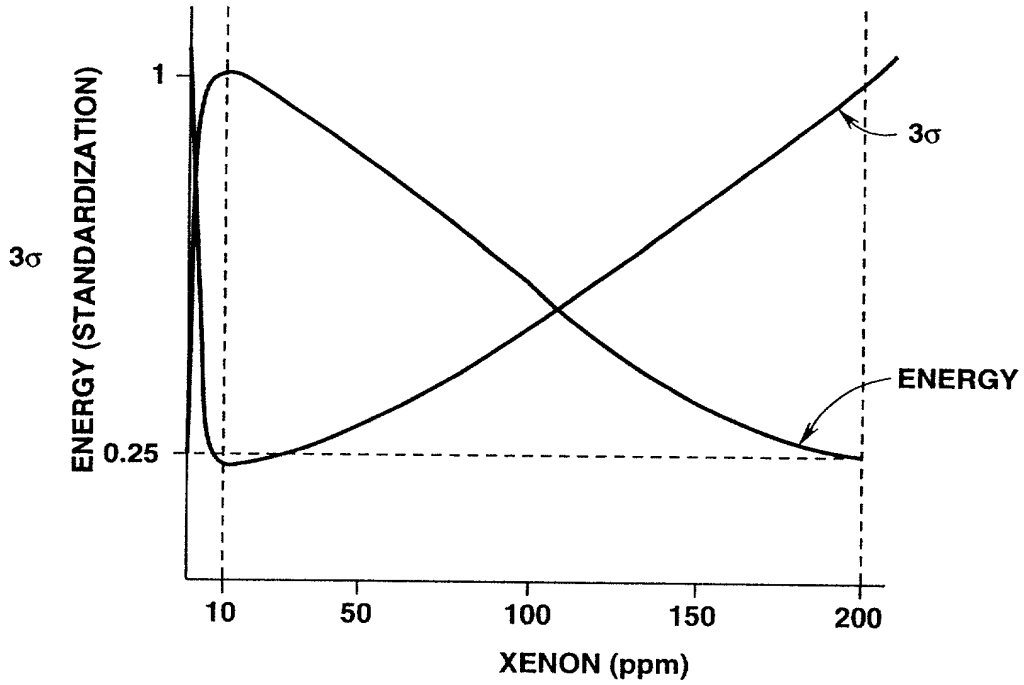

ENERGY (STANDARDIZATION)
1
0.25
3σ
3σ
ENERGY
10
50
100
150
200
XENON (ppm)

FIG.3

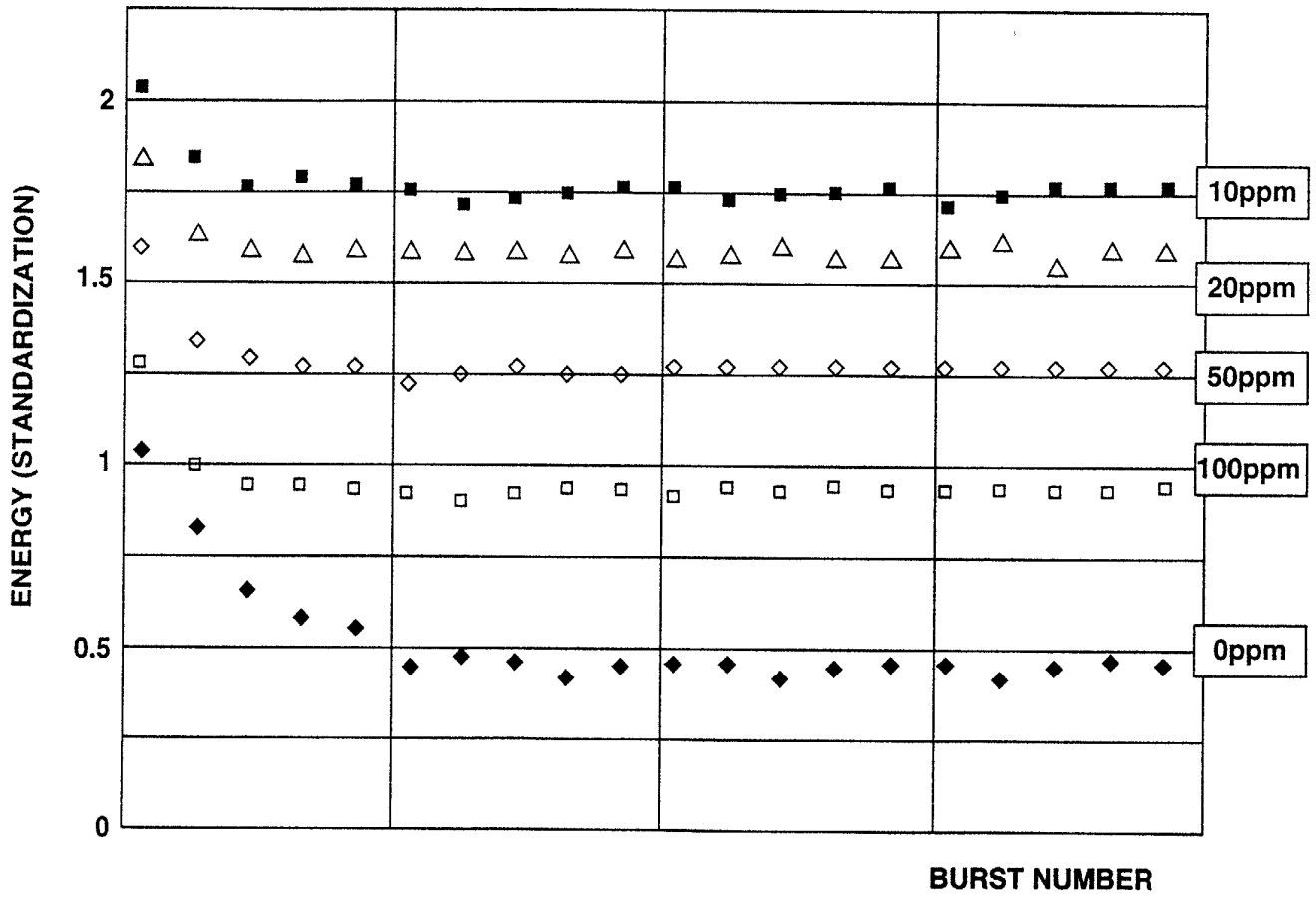

ENERGY (STANDARDIZATION)
2
1.5
1
0.5
0
BURST NUMBER
10ppm
20ppm
50ppm
100ppm
0ppm

FIG.4

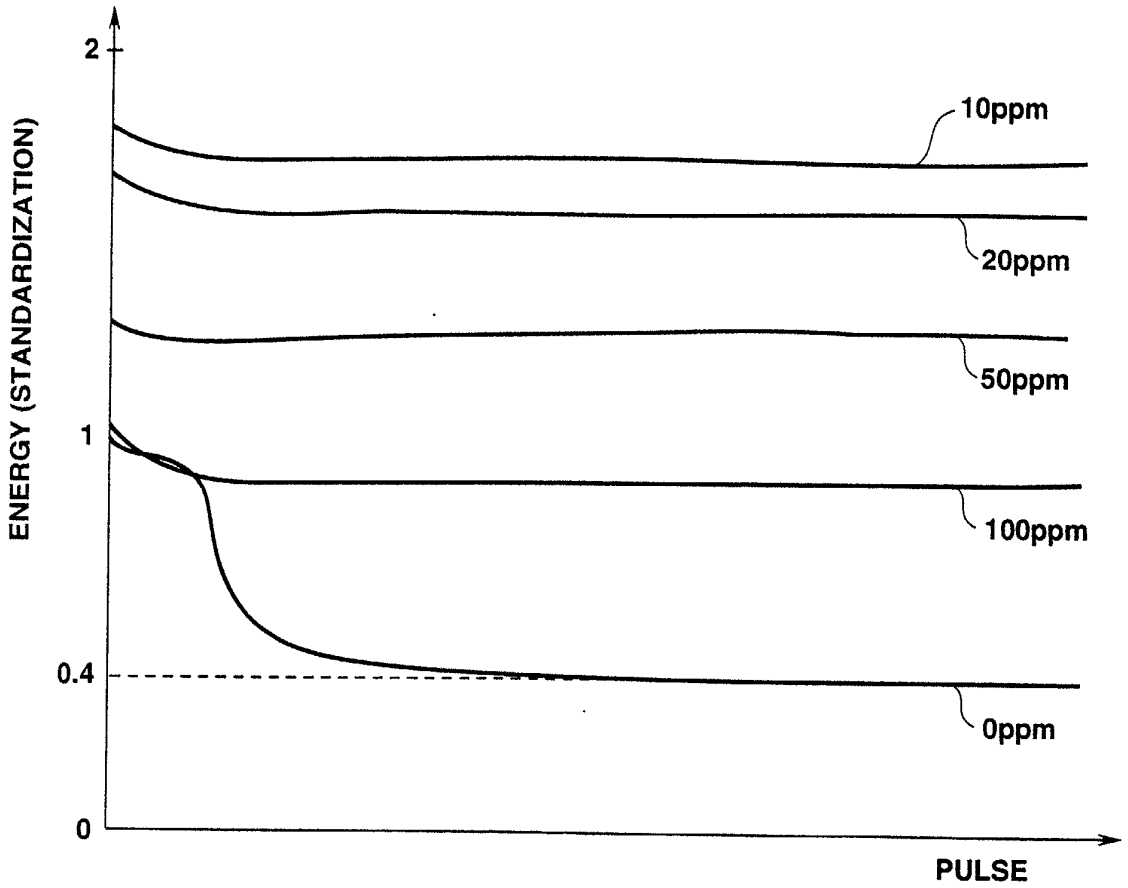

2
1
0.4
0
ENERGY (STANDARDIZATION)
10ppm
20ppm
50ppm
100ppm
0ppm
PULSE

FIG.5

FIG.6(a)

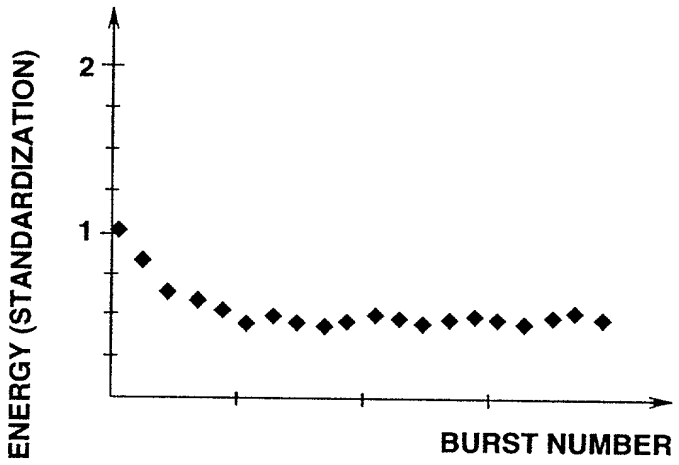
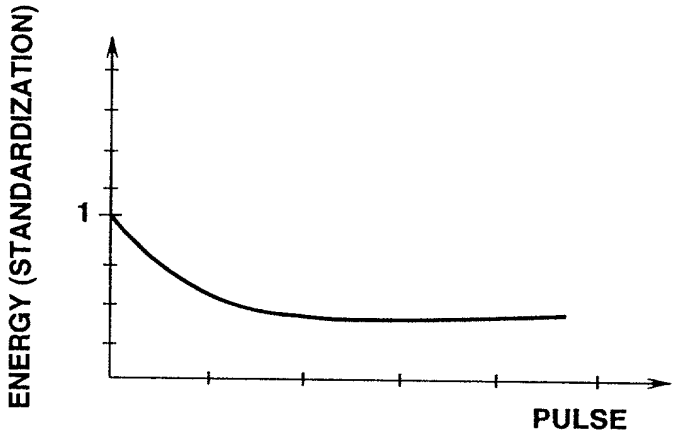


FIG.6(b)



(PRIOR ART)

PTO/SB/106 (8-96)
Approved for use through 9/30/98. OMB 0651-0032
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

EXCIMER LASER DEVICE AND GAS FOR EXCIMER LASER

上記発明の明細書（下記の欄でx印がついていない場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

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（該当する場合）_____ に訂正されました。

☐ was filed on _____
as United States Application Number or
PCT International Application Number
_____ and was amended on
_____ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第３７編第１条５６項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

PTO/SB/106 (8-96)
Approved for use through 9/30/98. OMB 0651-0032
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Japanese Language Declaration
(日本語宣言書)

私は、米国法典第３５編１１９条(a)-(d)項又は３６５条(b)項に基き下記の、米国以外の国の少なくとも一ヵ国を指定している特許協力条約３６５(a)項に基ずく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)
外国での先行出願

(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願年月日)	Priority Not Claimed 優先権主張なし
317692/ 1998	Japan	9/ November / 1998	☐
			☐

私は、第３５編米国法典１１９条(e)項に基いて下記の米国特許出願規定に記載された権利をここに主張いたします。

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)	(Application No.) (出願番号)	(Filing Date) (出願日)

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I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application.

(Application No.) (出願番号)	(Filing Date) (出願日)	(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)

私は、私自身の知識に基ずいて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じるところに基ずく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第１８編第１００１条に基ずき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の声明を行なえば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

PTO/SB/106 (8-96)
Approved for use through 9/30/98. OMB 0651-0032
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Japanese Language Declaration
(日本語宣言書)

委任状： 私は下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。（弁護士、または代理人の氏名及び登録番号を明記のこと）

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith *(list name and registration number)*

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（第三以降の共同発明者についても同様に記載し、署名をすること）

(Supply similar information and signature for third and subsequent joint inventors.)

Docket No. _____ (cont'd.)

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第六共同発明者		Full name of sixth joint inventor, if any	
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